BULLETIN 191 JULY 1920

The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

A HELMINTHOSPORIUM DISEASE OF WHEAT AND RYE

BY
LOUISE J. STAKMAN
Formerly of
DIVISION OF PLANT PATHOLOGY AND BOTANY

UNIVERSITY FARM, ST. PAUL

ADMINISTRATIVE OFFICERS

R. W. THATCHER, M.A., D.Agr., Director
ANDREW BOSS, Vice Director
A. D. WILSON, B.S. in Agr., Director of Agricultural Extension and Farmers' Institutes
O. I. BERGH, B.S., Agr., Superintendent, North Central Substation, Grand Rapids
M. J. THOMPSON, M.S., Superintendent, Northeast Substation, Duluth
C. G. SELVIG, M.A., Superintendent, Northwest Substation, Crookston
R. E. HODGSON, B.S. in Agr., Superintendent, Southeast Substation, Waseca
P. E. MILLER, B.S.A., Superintendent, West Central Substation, Morris
CHARLES HARALSON, Superintendent, Fruit Breeding Farm, Zumbra Heights (P. O. Excelsior)
W. H. KENETY, M.S., Superintendent, Forest Experiment Station, Cloquet
W. P. KIRKWOOD, B.A., Editor
ALICE MCFEELY, Assistant Editor of Bulletins
HARRIET W. SEWALL, B.A., Librarian
T. J. HORTON, Photographer
R. M. WEST, B.S., Secretary
R. A. GORTNER, Ph.D., Chief, Division of Agricultural Biochemistry
ANDREW BOSS, Chief, Division of Agronomy and Farm Management
C. W. GAY, B.S.A., D.V.M., Chief, Division of Animal Husbandry
FRANCIS JAGER, Chief, Division of Bee Culture
C. H. ECKLES, M.S., Chief, Division of Dairy Husbandry
*JOHN T. STEWART, C.E., Division of Drainage
W. A. RILEY, Ph.D., Chief, Division of Entomology and Economic Zoology
WILLIAM BOSS, Chief, Division of Farm Engineering
E. G. CHEYNEY, B.A., Chief, Division of Forestry
W. H. ALDERMAN, B.S.A., Chief, Division of Horticulture
E. M. FREEMAN, Ph.D., Chief, Division of Plant Pathology and Botany
A. C. SMITH, B. S., Chief, Division of Poultry Husbandry
J. D. BLACK, Ph. D., Chief, Division of Research in Agricultural Economics
F. J. ALWAY, Ph.D., Chief, Division of Soils
C. P. FITCH, M.S., D.V.M., Chief, Division of Veterinary Medicine

STAFF OF DIVISION OF PLANT PATHOLOGY AND BOTANY

E. M. FREEMAN, Ph.D., Plant Pathologist and Botanist, Chief

Section of Plant Pathology

E. C. STAKMAN, Ph.D., Plant Pathologist
G. R. BISBY, Ph.D., Assistant Plant Pathologist
F. JEAN MACINNES, M.S., Mycologist
H. D. BARKER, M.S., Assistant in Plant Pathology
G. F. PUTTICK, B.S., Assistant in Plant Pathology
LOUISE DOSDALL, Assistant in Plant Pathology

Section of Seed Laboratory

R. C. DAHLBERG, B.S., Seed Analyst, Acting
A. H. LARSON, B.S., Assistant Seed Analyst
BEATRICE LARSON, M.A., Assistant Seed Analyst

Section of Plant Physiology

L. I. KNIGHT, Ph.D., Plant Physiologist

*On leave of absence.

CONTENTS

ILLUSTRATIONS

SUMMARY

1. A wheat disease caused by a species of Helminthosporium has been observed in Minnesota for several years. It is widespread and important but not alarming.
2. The disease causes a foot rot of seedlings which may or may not result in the death of the plants. Areas of varying size in the field may be affected, or the diseased seedlings may be scattered.
3. Secondary infections may occur on leaves, nodes, internodes, glumes, and seeds. The lesions are brown at first, but later become dull tan in color with a distinct, brown border.
4. Common bread wheats, durum varieties, club wheats, emmer, einkorn, and rye are susceptible. Many grasses can easily be infected.
5. A similar disease occurs on rye. A strain of the causal organism which has been isolated from rye seed infected wheat, barley, and several grasses.
6. The disease is seed-borne and is not eliminated by the ordinary formaldehyde treatments.
7. Control measures consist in the use of seed from uninfected fields and in good cropping methods.
8. Further investigations are in progress.

A HELMINTHOSPORIUM DISEASE OF WHEAT AND RYE

By Louise J. Stakman [1]

INTRODUCTION

A seedling blight of wheat has been observed in Minnesota occasionally since 1910. Helminthosporium and other fungi were often associated with the disease and preliminary work indicated that it was of the general type described by Bolley.[2] Apparently the disease was not especially serious, and for that reason it was not investigated thoroly.

In 1918, however, several plots of hybrid wheat at University Farm had to be discarded entirely on account of a disease similar to that which had been seen in the field. The symptoms were so characteristic and the damage was so great that investigations were begun.

During the early summer of 1919 many county agents and grain growers throughout the state became concerned on account of the damage done by a seedling blight and foot rot of wheat. Numerous specimens were sent to the experiment station for identification, and it soon became evident that the disease was similar to that which had been observed in previous years. The indications also were that the disease might be identical with the one which had developed in such serious abundance on several plots of hybrid wheats during the previous year. Evidently, however, the disease was much more widespread and more destructive than it apparently had been before. The writer therefore visited several of the most important wheat-growing counties of the state in order to study the disease in the field.

Very clearly the seedling blight not only was widely distributed but was also quite destructive. Diseased plants were obtained from nearly every important wheat-growing county of the state. The damage in individual fields ranged from a fraction of 1 per cent to as much as 50 per cent, altho some of the diseased plants recovered partially or entirely later in the season. Marquis seemed to be more severely affected than other varieties except the hybrids previously mentioned. Too much significance should not be attached to this fact, however, because Marquis is so much more commonly grown than other varieties that its greater susceptibility may have been apparent only. The disease also was observed on Arnautka, Kubanka, Mindum,

[1] Formerly Mycologist, Division of Plant Pathology and Botany.

[2] Bolley, H. L., "Root diseases of cereals and soil studies." N. Dak. Agr. Exp. Sta. 22nd. Ann. Rept. 1912.

and several unclassified durums, as well as on Kanred, Sonora, Haynes bluestem, Glyndon fife, einkorn, and emmer.

A similar disease on rye was observed in several localities. One field of rye in the northern part of the state was so seriously affected with seedling blight as to be damaged severely.

SYMPTOMS

Two distinct types of injury are caused by the disease. The most striking symptom is seedling blight of wheat and rye plants. Careful observations in the field, as well as controlled experiments in the field, greenhouse, and laboratory, show clearly that the causal organism also attacks older plants.

Early in June the most conspicuous symptoms in the field were a distinct dwarfing of the seedlings and a foot and root rot. Usually the diseased plants were in scattered patches of varying size. These reddish brown diseased areas contrasted sharply with unaffected parts of the field. They sometimes included only a small portion of the drill row, and sometimes most of the plants in an area 75 feet or more in diameter. As a rule practically all of the plants in these areas were uniformly small and discolored. At the edge of the patch there was a gradual transition from the stunted plants to entirely normal seedlings. In other fields there were no definite diseased areas, but there were numerous diseased seedlings scattered throughout the field.

The leaves of the most heavily infected plants were pale reddish tan in color, very narrow, and about one-third as long as those of the normal plants. In the early stages of the development of the disease there were numerous lesions at the bases of the culms. Sometimes these lesions were small, streak-like, and rust-brown in color; sometimes, however, they formed blotches involving most of the foot. As the disease progressed the inner sheaths began to be infected. The leaf blades became discolored and died from the tips backwards.

The roots also were affected. Sometimes they became entirely brown, or, again, they were practically covered with small irregular brown lesions. Often the roots were so badly diseased that the cortex was torn off entirely when the plants were pulled from the ground, leaving only the vascular elements.

Plants which were not killed in the seedling stage apparently often recovered and grew to maturity. An especially severe attack of the disease occurred again in 1919 in a plot of hybrid wheat at University Farm. Many of the seedlings were attacked and quickly killed. Some of the plants which had been infected as seedlings matured, altho very

few entirely escaped the disease. It was found by carefully observing individual plants at frequent intervals that some of the foot lesions which were formed when the seedlings were only a few inches high persisted until the plants were mature. The permanent damage in this plot was greater than that observed in any other field. However, in many other fields the seedling blight was followed by serious injury to the older plants.

The symptoms of the secondary infection on older plants are very characteristic. On the leaves, numerous dark brown spots about one mm. long develop. At first these spots are very sharp, but later they become paler in color and often coalesce. The nodes also are affected. Small dark brown spots, similar in appearance to those on the leaves, enlarge and coalesce, so that generally the entire node becomes involved. The color of these diseased nodes changes to dull tan, and their edges are bordered by fine, horizontal, dark brown lines. Often the discolored areas become coated with Helminthosporium spores, thus developing a black, velvety appearance. Green or brown streaks may extend from the infected nodes to the internodes. Sometimes, however, the internodes become more uniformly brown. Numerous small brown lesions often develop on the necks and on the glumes. On the latter these lesions increase in size and finally become pale tan in color, with a faint brown border. When the glumes are severely affected the head appears conspicuously bleached. Helminthosporium sporulates freely on these diseased areas, but often other fungi also develop and the color of the heads then becomes very dark.

Seeds often also become badly diseased. Dark brown blotches, irregular both in size and shape, may cover practically the entire seed. The appearance is distinct from that of the so-called black tip. On the immature seeds the lesions appear as the typical small brown spots previously described. The discoloration may become quite indistinct on the mature seeds, altho when such seeds are planted they develop severely diseased seedlings. Badly diseased plants sometimes produce small shrivelled seeds.

CAUSE OF THE DISEASE

A species of Helminthosporium was very commonly associated with the seedling blight as well as with the lesions on the older plants. In fact this association was so universal that one would almost be tempted to conclude immediately that the disease was caused by Helminthosporium, were it not for the fact that the fungus is found so often on dead plant parts.

Isolations were made from all types of lesions on a great many plants from many different fields in all parts of the state. Helminthosporium was isolated with monotonous regularity. While Fusarium and other fungi sometimes were isolated from diseased seedlings, subsequent inoculation experiments proved that the disease symptoms caused by these fungi, if indeed they were pathogenic at all, were quite distinct from those symptoms which very clearly were caused by Helminthosporium. Numerous isolations of Helminthosporium were made from lesions on Marquis wheat, from leaf spots on Arnautka, blighted seedlings of emmer, einkorn, Kanred, and Kubanka, and of several unclassified durums, including a black macaroni. Isolations also were made from seeds of Mindum, Kubanka, and wheat hybrids, and from the culms of Haynes bluestem, Glyndon fife, Kubanka, Marquis × Iumillo hybrids, and Kubanka × Marquis hybrids. Pure cultures of Helminthosporium also were obtained from seeds, seedlings, and culms of affected rye plants. Numerous inoculation experiments proved conclusively that Helminthosporium caused all the disease symptoms which have previously been described. A single spore strain obtained from an infected node of a Marquis × Iumillo hybrid was used in most of the inoculation experiments that are described later.

The disease was reproduced by inoculating the seed and soil, by planting diseased seed in sterilized soil, and by inoculating various parts of old plants. Numerous cross-inoculation experiments showed that the organism is capable of attacking many cereals and grasses in addition to wheat and rye.

INOCULATION EXPERIMENTS

INOCULATIONS ON WHEAT SEED

Marquis and Kubanka wheat seeds were inoculated with several strains of Helminthosporium in the greenhouse. In each experiment the soil was sterilized either by steam or with formalin. In the first series, seeds were soaked one-half hour in water, two minutes in a 0.2 per cent solution of mercuric chloride in 50 per cent alcohol, and then washed in running water. In the first two series the seeds were immersed in a spore suspension before planting, and bits of the culture were added to the soil. In the third series rice was used as a medium for the fungus, and the whole culture was buried in the soil near the seeds. Sterile agar or rice was added to the checks. In the last two series the pots were left in a moist chamber for forty-eight hours.

Within about a week after inoculation, brown lesions began to appear on the stems of inoculated seedlings. Sometimes these lesions

remained as small streaks, 1 to 4 mm. long by 1 mm. or less wide, but often the whole foot became brown. At first the infected seedlings were shorter than the checks, but later this difference was less marked. A few of the typical leaf spots developed. Some of the roots became entirely brown. In the less discolored portions of diseased roots only the cortex was infected. Toward the root tip the vascular portion also was generally partially destroyed, and separated readily from the cortex. A few of the most heavily inoculated plants died in the same manner as those which had been observed in the field. Table I summarizes the results of these inoculations.

TABLE I

RESULTS OF INOCULATING WHEAT SEED WITH HELMINTHOSPORIUM

Source of culture	Variety inoculated	No. seeds germinated	Length of observation in days	Mean height of seedlings in cm.	Number of foot lesions	Number of leaf lesions
Marquis × Iumillo node, St. Paul	Marquis	78	38	29	39	19
Check	Marquis	70	38	36	1	0
Kubanka node, St. Paul	Kubanka	38	38	30	16	5
Check	Kubanka	35	38	33	0	0
Marquis seedling, Thief River Falls	Marquis	37	30	.....	29	2
Check	Marquis	35	30	.....	15	0
Marquis seedling, Newfolden	Marquis	23	30	.....	21	.....
Check	Marquis	31	30	.....	14	.....
Marquis × Iumillo node, St. Paul	Marquis	60	22	19	54	8
Check	Marquis	68	22	25	0	0

Since the Marquis seed was already infected to some extent with Helminthosporium, a few typical lesions appeared on the check plants, especially in the second series of inoculations. When the infected leaf-bases had dropped off, some of the diseased seedlings recovered, as did many in the field.

EFFECT OF PLANTING NATURALLY INFECTED SEED

Shriveled seed from discolored heads of Kubanka which had been grown in a badly infected plot, were planted in sterilized soil. Of the infected seeds planted, 31 out of 40 germinated and produced plants which were much smaller and weaker than the checks. The sheaths

were brown and the discolored area sometimes extended down through several leaf bases. Similar symptoms developed on a few secondary shoots of the plants. Infected roots were usually short and thin, somewhat brown, with an occasional darker brown band, especially near the tip. Helminthosporium was isolated easily from the diseased shoots and roots.

Marquis wheat from the original seed lot, sown in a blighted field near Battle Lake, Minnesota, was thickly planted in flats in the greenhouse. Within three weeks a large proportion of the seedlings were blighted and had developed brown bases and narrow, pinkish leaves. When seeds from the same lot were planted on agar, several Helminthosporium-infected seedlings were produced whose leaves died very rapidly.

Some seeds from one of the diseased hybrid wheats previously mentioned were planted in pots of sterilized white sand, some in sterilized garden soil, and a third lot in unsterilized garden soil. Typical foot and root lesions developed again, showing clearly that the disease is seed-borne. A few of the seedlings produced secondary shoots, which in turn became infected. Foot lesions appeared on 59 of the 72 seedlings which developed. The disease was about equally severe in each of the different kinds of soil. The healthy plants which developed were much taller and stouter than those which were diseased.

Helminthosporium again was isolated from diseased plants. Fusarium also was obtained from a few of them, but this fungus seems to kill the seedlings more rapidly. It causes a softer rot of the tissue at the base of the plant, and the discoloration is less pronounced. This difference also was noted in the field. It is possible, therefore, to distinguish between the symptoms caused by Helminthosporium and those caused by Fusarium.

In another experiment the seeds from 51 hybrid selections, 17 Iumillo × Marquis, 17 Marquis × Iumillo and 17 Kubanka × Marquis, were planted in the field. All had been discarded from the rust nursery in the 1918 harvest on account of Helminthosporium injury. The seed germinated very poorly and most of the seedlings which did grow were weak and small. Individual plants died at various times during the entire season, until at harvest time the stand was very poor. Most of the foot lesions persisted, and when new shoots were developed, they also became similarly infected. This resulted in the production of many small shoots, and some of the plants developed a distinct rosette appearance. This clearly was due to Helminthosporium, and pure cultures of the fungus were easily obtained. There were many dwarfed plants with dwarfed heads. Other hybrids in

the rust nursery developed more nearly normally, altho there was at least a trace of the disease in most of the plots.

INOCULATIONS OF MATURING PLANTS

Early in July various plant parts of Marquis wheat were inoculated with sporulating cultures. The inoculated parts were covered with moist cotton and oiled paper caps for 48 hours. Adequate checks were run. The results are given in Table II.

TABLE II

RESULTS OF INOCULATING MATURING PLANTS WITH HELMINTHOSPORIUM

Part of plant inoculated	Number of inoculations	Number of infections
Top of head	10	8
Middle of head	21	18
Between glumes of whole head	60	45
Head still in sheath	15	14
Neck	20	10
Node	17	15
Check	15	0

Typical lesions developed at the point of inoculation. On the glumes the first evidence of infection was the appearance of small brown blotches. These latter enlarged, became pale in color with dark borders, and finally spread over the whole glume, giving it a bleached appearance. Spores developed even on spots which were only 2 or 3 mm. wide. When the inoculum was placed between the glumes, the infection was so severe that many of the seeds became badly discolored.

The neck was not especially susceptible, the chief sign of disease being the development of a narrow purple-brown line around the stem from the point of inoculation. In a few cases the infection extended a few millimeters downward from this point. On the nodes, minute dark brown spots first appeared. These developed into pale brown-bordered spots, covering most of the node, and were in every way typical of the naturally occurring spots. Sometimes the adjacent internodes became brown in the immediate vicinity of the node.

Inoculations were made on plants at different stages of development in order to get evidence as to the age of greatest susceptibility. The disease developed more rapidly both on the older heads, 2 to 5 days out of the sheath, and on the older nodes. When puncture inoculations were made the disease spread more quickly than when inoculations were made without injuring the plants.

CROSS-INOCULATIONS WITH HELMINTHOSPORIUM

The strain of Helminthosporium from the node of the hybrid wheat was used to inoculate grasses and other cereals in the greenhouse. Most of the inoculations were made with a flat needle near the tips of the leaves and under the leaf bases of larger leaves; but narrow-leaved forms were merely sprayed with water containing spores in suspension. The plants were left in a moist chamber for 48 hours, after which they were placed on a greenhouse bench where they were examined daily for several weeks. In the last series of inoculations the spores failed to germinate on the leaves during the first period of incubation, owing to the fact that a film of water was not deposited on the leaves. When the water was supplied, germination and infection followed. Apparently the spores require water for germination, since they did not germinate in moist air. The results of the cross-inoculations are given in Table III.

TABLE III

RESULTS OF CROSS-INOCULATIONS WITH HELMINTHOSPORIUM FROM WHEAT NODE

Host	Age of plants in days	Method of inoculating	Number of inoculations	Number of infections
Rye				
Spring	8	With needle	31	5
Swedish, Minn. 2	17	"	12	8
Wheat				
Marquis, Minn. 1239	10	"	33	33
Marquis, Minn. 1239	5	"	22	22
Kota, C. I. 5878	10	"	12	10
Turkey, C. I. 1558	19	"	12	7
Cosgrove, Minn. 1487	17	"	12	10
Monad, C. I. 3320	13	"	12	12
Einkorn, C. I. 2433	13	"	12	12
Emmer, Minn. 1165	14	"	12	12
Arnautka, C. I. 4072	14	"	12	10
Corn	112	"	12	0
Stipa viridula		"	8	8
Eleusine indica		"	10	9
Agropyron repens		"	32	25
Setaria verticillata		"	12	12
Dactylis glomerata	46	"	12	5
Phleum pratense	46	"	12	0
Festuca heterophylla	118	Sprayed		0
Festuca ovina	118	"		Numerous
Festuca ovina duriuscula	118	"		Numerous
Festuca tenuiflora	118	"		Numerous
Festuca rubra		"		Trace
Agrostis alba vulgaris	118	"		0
Agrostis canina	118	"		0
Poa trivialis		"		0
Phalaris canariensis	117	"		0
Alopecurus geniculatus	118	"		0
Danthonia spicata	117	"		0
Anthoxanthum odoratum	118	"		Numerous

There was a conspicuous difference in the susceptibility of plants of different ages. For instance, the younger plants of Marquis produced mostly large, dull gray to tan, watery areas, sometimes with slightly darker edges, while on older plants small dark brown spots first appeared. These latter eventually coalesced, forming the typical tan leaf spots with brown borders. Only the large water-soaked spots were produced on rye, Monad and Kota wheats, and Setaria. A few of the other species developed both kinds of spots but most of them produced only the small brown lesions. No real spots developed on corn, but there was sometimes a slight discoloration at the point of inoculation. The number of small spots on a leaf increased, probably on account of the distribution of spores by plant lice and moisture. Leaves from fifteen of the diseased plants were cultured and Helminthosporium was recovered from all of them. Extensive cross-inoculations also were undertaken in the field but the results were not entirely conclusive and the work must be repeated.

Cross-inoculations were made in the greenhouse with Helminthosporium obtained from infected seeds of spring rye.[3] In all cases a spore suspension was sprayed on to the plants, which were then incubated in a moist chamber for forty-eight hours.

In this work again it was found that young seedlings were less susceptible to leaf spot than older ones. The following plants were inoculated at intervals of two or four weeks to prove this point: Little Club wheat, Kota, emmer, einkorn, *Agropyron smithii, Elymus virginicus,* and *Hordeum jubatum.*

The first signs of infection were small water-soaked spots which generally developed into the typical brown lesions. On Swedish rye and *Bromus tectorum* the diseased areas never became characteristically brown, but remained water-soaked in appearance until they died out.

This corresponds with the effect of the wheat forms on several hosts. On inoculated corn the same flecks appeared as when Helminthosporium from wheat was used. Table IV summarizes the results of these inoculations.

There are similarities as well as differences in the action of the Helminthosporium from wheat and rye on the various hosts. However it is not possible to conclude from preliminary tests of this kind whether the two strains are identical.

[3] These inoculations were made by J. J. Christensen, a student in the Division of Plant Pathology and Botany, to whom the writer wishes to express her grateful appreciation for exceptionally efficient help.

TABLE IV

RESULTS OF CROSS INOCULATION WITH HELMINTHOSPORIUM FROM RYE SEED

Host	Age of plants in days	No. of plants inoculated	Degree of infection*
Wheat			
Marquis, C. I. 3641	12	29	+
Cosgrove, Minn. 1487	12	20	+ −
Kanred, C. I. 5146	15	18	+ −
Kanred, C. I. 5146	19	18	+ −
Kota, C. I. 5878	15	15	+
Kota, C. I. 5878	17	15	+
Mindum, C. I. 5296	12	21	+ −
Kubanka, C. I. 2094	32	17	+ −
Kubanka, C. I. 2094	46	17	+ −
Arnautka, C. I. 4072	18	9	+ −
Acme, C. I. 5284	12	18	+ −
Emmer, C. I. 3686	46	30	+
Emmer, C. I. 3686	63	30	+
Emmer, C. I. 3686	12	18	+
Khapli, C. I. 4013	12	20	+ −
Einkorn, C. I. 2433	46	20	+
Einkorn, C. I. 2433	19	18	+
Little Club, C. I. 4066	70	7	+
Little Club, C. I. 4066	87	7	+
Little Club, C. I. 4066	19	18	+
Little Club, C. I. 4066	87	7	+
Spelz Marz, Minn. 337	12	41	+ −
Barley			
Manchuria, Minn. 105	41	27	+ −
Manchuria, Minn. 105	26	27	+ −
Rye			
Swedish, Minn. 2	46	50	+ −
Swedish, Minn. 2	46	30	+ −
Oats			
Ligowa, Minn. 281	57	15	−
Oklahoma	74	15	−
Oklahoma	57	20	−
Corn	15	9	−
Corn	18	10	−
Agropyron smithii	37	14	+ −
Agropyron smithii	47	14	+ −
Agropyron repens	30	30	+ −
Agropyron repens	47	30	+ −
Bromus tectorum	30	40	+ −
Bromus tectorum	47	40	+ −
Dactylis glomerata	30	30	−
Elymus virginicus	42	40	+
Elymus virginicus	59	40	+
Hordeum jubatum	30	42	+ −
Hordeum jubatum	47	42	+ −
Hordeum pusillum	87	40	+ −
Phleum pratense	30	40	−
Lolium perenne	12	50	+ −
Lolium perenne	22	50	+ −

* +=abundant infection
+ −=moderate infection
−=no infection

In 1913, a series of inoculations was made by E. C. Stakman on wheat seeds and seedlings with a Helminthosporium isolated from barley. The results are given in Table V.

TABLE V

RESULTS OF INOCULATING WHEAT SEEDLINGS WITH HELMINTHOSPORIUM FROM BARLEY

Method of inoculating	No. plants inoculated	No. plants diseased	Character of lesions
Agar culture mixed with sterilized soil	25	2	Dark lesions on culm and sheath; not extending one cm.
Seeds soaked in suspension of spores in water	10	0	
Soil watered with suspension of spores in water	21	4	Dark lesions on culm and sheath; not extending one cm.
Check	20	0	
Mycelium and spores placed on leaf	25	18	Dark brown or "scorched" lesions 2.5–10mm × 2–4mm.

In another experiment sterile durum wheat seedlings growing in an agar based upon Sach's modified solution were inoculated with Helminthosporia from barley. *H. gramineum* had very little effect. A second species, tentatively determined as *H. sativum* P. K. & B. by Dr. A. G. Johnson, produced 100 per cent infection in nine trials on durum, causing the roots to become much shortened and brown-mottled. Distinct brown lesions, similar to those found on diseased wheat plants in the field, appeared at the bases of the stems and on the leaves. In the root, the chief seat of infection was just outside the endodermis. Large, nearly hyalin hyphae were found between and within the cells, the walls of which became yellow.

SOURCE OF INFECTION

It is possible that initial infection in the field may come both from the seed and from the soil, but, so far, we have definite proof only of the former. Definite areas of seedling blight in the field at first suggested soil infection, but the spots were very numerous and scattered. They seemed to have no definite relation to contour, sometimes occurring in hollows, sometimes on hillsides, sometimes on the level portions of the field. Blighted plants were found on several soil types and in fields with various crop histories. No correlation, therefore, could be made either with soil type or with previous crop history. The diseased spots were found in sandy loam, gumbo, and peat lands. One of the fields in which the disease occurred had grown timothy the preceding year, another had grown alfalfa for two years, another had been summer fallowed. At the Minnesota Experiment Station, soil in which the diseased hybrids had grown the previous year was removed to another plot and planted to Marquis, but there was little

infection. Johnson[4] found that greenhouse soil containing Helminthosporium retained for six months its capacity for infecting wheat.

Wheat seed has often been found infected with Helminthosporium. Bolley[5] mentions Helminthosporium often as one of his imperfect fungi infecting seed and soil. Several of the experiments described above demonstrate seed infection. The seed lot referred to on page 10 looked very plump and healthy in the bin, but, when examined closely, it was found to contain typically discolored seeds. In a field plot where the seed was inoculated with Helminthosporium spores there was a noticeable amount of seedling blight.

TIME OF INFECTION

There seems to be some relation between the age of the plants and the amount of infection. In the greenhouse it was found that very young seedlings were less susceptible to the small brown leaf spots than older plants. On Marquis plants five days old, areas of the leaf tended to dry out, while on plants ten days old the small brown leaf spot was produced. There were comparatively few leaf spots on blighted seedlings. In the field, leaves seemed less susceptible when artificially inoculated in the very young stages and after heading out. As a result of field inoculations made in July, it was evident that, with the exception of leaves, the parasite spread most rapidly on older plant parts. Marquis planted between the 10th and the 18th of May, later than the other wheat, in plots at University Farm, showed less typical Helminthosporium node infection than most of the earlier plantings, altho both seed and soil of the former had been inoculated. Plants from the heavily infected seeds sown at the same time as the late sowing of Marquis were severely injured, but the damage was due chiefly to the initial infection at the base, rather than to secondary infection on the nodes or upper parts of the plants.

EFFECT OF WEATHER CONDITIONS

Weather conditions, of course, are intimately involved in differences in susceptibility. In the northern part of Minnesota the disease had appeared and developed rapidly during an interval of dry weather, preceded by a week of rain. Wind and rain followed and, as a result, the dead plants were blown away or buried. Many of the less severely affected plants were recovering by sending out new shoots. In the

[4] Johnson, E. C. "A study of some imperfect fungi isolated from wheat, oat, and barley plants." Jour. Agr. Research 1: 475-490. 1914.

[5] Bolley, H. L. "Wheat: soil troubles and seed deterioration." N. Dak. Agr. Exp. Sta. Bull. 107. 1913.

greenhouse abundant moisture was necessary for good infection. It seems likely that the disease will not be especially serious in seasons when the weather is fairly normal. Probably most damage will be done after plants already are weakened by unfavorable growing conditions.

THE FUNGUS

The fungus has not yet been studied culturally or morphologically in detail. It is possible that not all of the phases of the disease are caused by one species of Helminthosporium. With the exception of a few small-spored forms, the majority of cultures obtained from wheat resemble each other closely. The vegetative growth is fluffy, white and dark blue-green in color, with small compact white tufts of mycelium, such as occur on a number of Helminthosporia. On potato-dextrose agar, sweet clover stems, and other favorable media, spores are produced in abundance, forming an intense greenish black, powdery coating over the substratum and giving the appearance of stippling. A very characteristic feature, at least in culture on potato-dextrose agar, is a pleasant, anise-like odor. The spores are either straight or curved, and are dark blue-green to brown in color. They average 41x20 microns and contain 3 to 8 septa. In notes made by E. C. Stakman, in 1913, two types of spores from a specimen of wheat are mentioned, the one a fuscous type measuring 35x22 microns and containing 3 to 4 septa; the other, straw-colored to fuscous, 60x20 microns, and containing 4 to 7 septa. All of these latter are described as elliptical. In shape the spores resemble those of Helminthosporium sativum, but they contain fewer septations and are shorter than those described by Pammel, King, and Bakke.[6] Until further comparative studies are made on the possible variation of Helminthosporium spores it does not seem advisable to refer the wheat fungus to any known species or to describe it as a new species.

CONTROL

Detailed studies on control have not been made, but in sterilizing seed for experimental purposes it was found that Helminthosporium was killed before Alternaria and several other molds, mercuric bichloride being an efficient agent. Long-time soaking in formaldehyde also reduced the amount of Helminthosporium. In some of the fields badly infected with seedling blight, the grain had been treated for smut.

[6] Pammel, L. H., King, C. N., and Bakke, A. L. "Two barley blights, with comparison of species of Helminthosporium upon cereals." Iowa Agr. Exp. Sta. Bull. 116. 1910.

but apparently the ordinary dip or sprinkling treatments do not kill the fungus in the seeds. Since it has been shown conclusively that the disease is seed-borne, clean seed is essential. Until more data on control measures become available, it is recommended that seed be obtained from healthy fields and that wheat be sown on land which has not grown a cereal or grass crop the previous year.

DISCUSSION AND CONCLUSIONS

For several years a destructive disease of wheat, caused by Helminthosporium, has been under observation in Minnesota. In the spring and early summer of 1919, serious attacks of seedling blight occurred in practically all wheat-growing regions of the state. The cause of this blight has been shown to be a species of Helminthosporium which also attacks practically all plant parts. On older plants it is often found associated with Septoria and Fusarium. All three may occur on one head or one node. All parts of the plant may be affected by Helminthosporium, altho there is no evidence that the disease is systemic. Since the foot and root may become seriously and permanently diseased, there is a possibility of new infection from stubble. This fact has an important bearing upon the subject of continuous cropping. A similar disease has been found on rye.

The disease clearly is seed-borne. Seedling blight almost always results from sowing diseased seed, altho the causal fungus apparently is less virulent than the wheat scab organism. Many infected seedlings revive. Some are left in a weakened condition and with an infection at the base. Secondary infections occur on leaf, culm, and head. The problem is at least partially one of clean seed wheat, but probably also of systems of cropping. While the Helminthosporium foot rot resembles somewhat the take-all as it develops in Illinois, there are certain differences and it can not be stated that the two diseases are identical. With our present knowledge it seems unsafe to call the disease as it has developed in Minnesota "take-all" or even to assume that it is identical with the foot rots described from other parts of the country.

The partial or almost complete recovery of many of the severely injured seedlings suggests that the disease need not cause undue apprehension on the part of wheat growers. Apparently the disease develops most abundantly when plants are weakened by unfavorable weather conditions. It is quite probable that losses can be minimized somewhat by good cropping methods. However, the disease certainly is capable of doing appreciable damage, and whatever control means suggest themselves as the result of the work done up to the present time should be applied in order that the disease may be kept in check.

Plate I. Marquis Wheat From a Field Affected With Helminthosporium Seedling Blight
At left, dying seedling. Note dark discoloration of foot.
In center, recovering seedling. The foot lesion is disappearing and new leaves are being formed.
At right, healthy plant from same field.

Plate II. Seedling Blight of Marquis Wheat Caused by Helminthosporium

The three pots at the left contain inoculated seed and soil. The three at the right are checks.

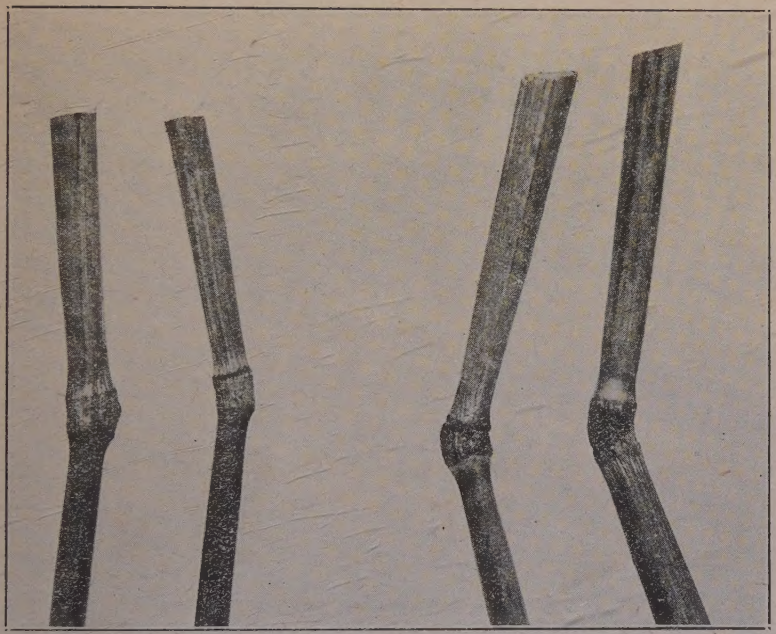

Plate III. Nodes and Internodes of Marquis Wheat Infected by Helminthosporium
At left, node, dull tan in color with brown lines at edges.
At right, node covered with coating of Helminthosporium spores.

Plate IV. Plot of Hybrid Wheat Almost Entirely Destroyed by Helminthosporium

Plate V. Closer View of Diseased Plot Pictured in Plate IV